12B, and 12C. Applicant has amended the specification and claims by replacing all occurrences of "bar-like" to "having a needle shape" or "needle-shaped" for clarity. Therefore, Applicant submits that claims 1-7, and 9 meet the definiteness criteria of 35 U.S.C. § 112 and request that the rejection be withdrawn. Applicant respectfully submits that the scope of the claims has not been narrow by this amendment for further clarity.

The Examiner rejected claims 1-9 under 35 U.S.C. § 102(b) as being anticipated by Ohtani et al. The rejection of claims 1-9 is respectfully traversed and reconsideration is requested.

Claims 1-5 are allowable over the cited reference in that these claims recite a combination of elements including, for example, a polycrystalline silicon film containing Ni atoms; an electrical conductivity activation energy between 0.52 eV and 0.71 eV and a plurality of needle-shaped silicon crystallites. Claims 6, 7 and 9 are allowable over the cited reference in that these claims recite a combination of elements including, for example, a polycrystalline silicon film containing metal; an electrical conductivity activation energy between 0.52 eV and 0.71 eV and a plurality of needle-shaped silicon crystallites. None of the cited references, singly or combined, teaches or suggests these features of the present invention. In particular, Ohtani et al. discloses a method of crystallizing silicon by heating and further by laser irradiation and does not disclose the electrical conductivity activation energy of the film, as claimed in the present invention. Therefore, the claimed invention is different from Ohtani et al.

In view of these distinguishing features, Applicant submits that there is no teaching or suggestion in the cited references to develop the polycrystalline silicon film as recited in independent claims 1, 3, 6, and 9. Applicant further submits that claims 2, 4, 5, and 7 are

allowable over the cited references at least because they depend from claims 1, 3, 6, and 9, respectively, which are believed to be allowable. Therefore, Applicant respectfully submits that claims 1-7, and 9 are allowable over the cited references.

Should the Examiner deem that a telephone conference would expedite the prosecution of this application, the Examiner is invited to contact the undersigned at (202) 624 1250.

If necessary, the Commissioner is hereby authorized in this, concurrent, and future replies, to charge payment or credit any overpayment to Deposit Account No. 50-0911 (8733.213.00) for any additional fee required under 37 C.F.R. §§ 1.16 or 1.17; particularly, extension of time fees.

Respectfully submitted,

LONG ALDRIDGE & NORMAN, LLP

By____________________
Song K. Jung
Reg. No. 35,210

Date: November 20, 2001

701 Pennsylvania Avenue, N.W.
Sixth Floor, Suite 600
Washington, D.C. 20004
Telephone: (202) 624-1200
Facsimile: (202)624-1298

EXHIBIT I – MARKED UP VERSION OF THE AMENDED SPECIFICATION PARAGRAPHS

Page 1, Paragraph Beginning at Line 4:

The present invention is related to a polycrystalline silicon film containing Ni which is formed by crystallizing an amorphous silicon layer containing nickel.

Page 1, Paragraph Beginning at Line 7:

In view of performance, low temperature polysilicon, [of which product] having low production cost [is low] owing to its low formation temperature and which also [enables to provide] provides a large-scale display area, is as good as high temperature polysilicon.

Page 1, Paragraph Beginning at Line 10:

There are various methods for forming low temperature polysilicon such as solid phase crystallization[(SPC),] SPC, laser crystallization and the like.

Page 1, Paragraph Beginning at Line 12:

[Enabling to provide] In providing low temperature crystallization under 400°C, [which is] as disclosed in (Hiroyaki Kuriyama, et[.] [al,] al., Jpn. J. Appl. Phys. 31, 4550 (1992)), the laser crystallization fails to provide uniform crystallization and has difficulty in forming polysilicon on a substrate of [an] a large area due to [an] the need for an expensive apparatus and low productivity.

Page 1, Paragraph Beginning at Line 17:

When polysilicon is formed by solid phase crystallization, uniform crystallites are attained [in use of] using an inexpensive apparatus. However, solid phase crystallization requires high temperature and long processing time [of] for crystallization, which is [hardly applied to forming polysilicon on] inappropriate for a glass substrate [thereby having high production cost].

Page 1, Paragraph Beginning at Line 21:

A new method of crystallizing amorphous silicon at low temperature, [which is so] called metal induced crystallization, is disclosed in (M.S. Haque, et[.] [al,] al., J. Appl. Phys. 79, 7529 (1996)). Metal induced crystallization crystallizes amorphous silicon by contacting amorphous silicon with a specific kind of metal which induces crystallization of silicon and then [by carrying out] subjecting it to annealing. [thereby enabling to lower] This allows the lowering of the crystallization temperature.

Page 2, Paragraph Beginning at Line 4:

In Ni-induced crystallization, crystallization is accelerated by the $NiSi_2$ which is the final phase of Ni silicide and works as a crystal nucleus, which is disclosed in (C. Hayzelden, et [al,] al., J. Appl. Phys. 73, 8279 (1993)). As a matter of fact, $NiSi_2$, [of] which has a lattice constant [is] of 5.406Å, similar to that of silicon which is 5.430Å, [of silicon,] also has [a similar] a structure [of] similar to silicon. Thus, $NiSi_2$ works as a crystal nucleus of amorphous silicon, accelerating crystallization to the direction <111>, which is disclosed in (C. Hayzelden, et[.] [al,] al., Appl. Phys. Lett. 60, 225 (1992)). The crystallization of amorphous silicon is accelerated by metal species.

Page 2, Paragraph Beginning at Line 12:

[The metal] Metal-induced crystallization is affected by time and temperature of annealing as well as quantity of metal, of which crystallization time is lowered in general [while] when the quantity of metal increases.

Page 2, Paragraph Beginning at Line 15:

Metal induced crystallization has [a merit] an advantage of low crystallization temperature, which unfortunately [requiring] requires long thermal process time of over 20 hours at 500°C. Therefore, this method has many difficulties [in being applied to] for mass production of polycrystalline silicon.

Page 2, Paragraph Beginning at Line 19:

As the quantity of metal increases, [so] metal induced crystallization becomes more effective. However, the intrinsic characteristics of a silicon film are changed due to metal contamination in the crystallized silicon film.

Page 2, Paragraph Beginning at Line 22:

As mentioned in the above explanation, despite the [merit] advantage of low temperature crystallization, metal-induced crystallization has a fatal defect in that the intrinsic characteristics of a silicon film [is] are changed due to [the] metal contamination [as] from the metal [having been] used for crystallization which remains in the crystallized silicon film.

Page 3, Paragraph Beginning at Line 6:

Accordingly, the present invention is directed to a polycrystalline silicon film containing Ni that substantially [obviate] obviates one or more of the problems due to limitations and disadvantages of the related art.

Page 3, Paragraph Beginning at Line 9:

[The] An object of the present invention is to provide a polycrystalline silicon film which contains metal species [properly] in an appropriate quantity by minimizing the metal contamination fatal to the polysilicon formed by metal-induced crystallization [in order to be used] for use in the fabrication of semiconductor devices.

Page 3, Paragraph Beginning at Line 18:

To achieve these and other advantages and in accordance with the purpose of the present invention, as embodied and broadly described, the present invention includes a polycrystalline silicon film wherein the polycrystalline film contains Ni atoms [of which] having a density in the [ranges] range of $2x10^{17}$ to $5x10^{19}$ atoms/cm^3 [in] on average and comprises a plurality of [bar-like] needle-shaped silicon crystallites.

Page 3, Paragraph Beginning at Line 23:

In another aspect, the present invention includes a polycrystalline silicon film wherein the polycrystalline film contains Ni atoms [of which] having a density in the [ranges] range of $2x10^{17}$ to $5x10^{19}$ atoms/cm^3 and comprises a plurality of needle-shaped [bar-like] silicon crystallites and is formed on an insulating substrate.

Page 4, Paragraph Beginning at Line 4:

In a further aspect, the present invention includes a polycrystalline silicon film wherein the polycrystalline film contains metal [of which] having a density in the [ranges] range of $2x10^{17}$ to $5x10^{19}$ atoms/cm^3 and comprises a plurality of needle-shaped [bar-like] silicon crystallites and wherein the metal is a catalyst for metal induced crystallization of silicon.

Page 4, Paragraph Beginning at Line 8:

In a further aspect, the present invention includes a polycrystalline silicon film wherein the polycrystalline film contains metal [of which] having a density in the [ranges] range of $2x10^{17}$ to $5x10^{19}$ atoms/cm^3 and the polycrystalline silicon film comprises a plurality of needle-shaped [bar-like] silicon crystallites and wherein the metal is a catalyst for metal induced crystallization of amorphous silicon.

Page 4, Paragraph Beginning at Line 17:

The accompanying drawings, which are included to provide a further understanding of the invention, [and are incorporated in and constitute a part of this application] illustrate embodiments of the invention [inventing] and together with the description serve to explain the principle of the invention.

Page 5, Paragraph Beginning at Line 3:

Fig. 3 shows a first example of the secondary ion mass-spectroscopy of a polysilicon film [formed by the] according to the first embodiment of the present invention;

Page 5, Paragraph Beginning at Line 7:

Fig. 5 shows a second example of the secondary ion mass-spectroscopy of a polysilicon film [formed by] according to the second embodiment of the present invention;

Page 5, Paragraph Beginning at Line 11:

Fig. 7 shows a third example of the secondary ion mass-spectroscopy of a polysilicon film [formed by] according to the third embodiment of the present invention;

Page 5, Paragraph Beginning at Line 15:

Fig. 9 shows a graph of an electrical conductivity activation energy vs. number of Ni atoms contained in the polysilicon film [formed by the embodiment of] according to the present invention;

Page 5, Paragraph Beginning at Line 18:

Fig. 10 shows field effect mobility of a TFT fabricated [in use] using the polysilicon film [formed by] according to another embodiment of the present invention in accordance with the Ni containment;

Page 6, Paragraph Beginning at Line 3:

In general, the metal induced crystallization is affected by time and temperature of annealing as well as quantity of metal [of] in which crystallization time is [lowered] reduced in general [while] when the quantity of metal increases. In this case, annealing time is dramatically shortened and annealing temperature is greatly reduced in metal induced crystallization provided that electric field is applied to [an] the amorphous silicon film containing the metal (Jin Jang, et[.] [al,] al., Nature, Vol. 395, pp.481-483 (1998)).

Page 6, Paragraph Beginning at Line 9:

The polysilicon film of the present invention is distinguished by the [facts] fact that the film is fabricated by metal induced crystallization [in use of] using Ni and [that] Ni atoms exist in the film [to the] in an extremely small amount between $2x10^{17}$ to $5x10^{19}$ atoms/cm^3.

Page 6, Paragraph Beginning at Line 12:

The polysilicon film of the present invention is formed by metal induced crystallization including the steps of adding a small quantity of Ni to an amorphous silicon film and carrying out rapid thermal process or another thermal treatment while electric field is applied thereon.

Page 6, Paragraph of Beginning of Line 16:

Ni is a catalyst for crystallizing a silicon film. [Besides] Other various metal species such as Au or Co [working] acting as a catalyst for metal induced crystallization can also [enable to] be used for the crystallization.

Page 6, Paragraph Beginning at Line 19:

[From now on] At this time, the description [will be followed by the case that] of how Ni is used as a catalyst for metal induced crystallization is presented.

Page 6, Paragraph Beginning at Line 23:

An amorphous silicon film is deposited on an insulating layer. Then, the amorphous silicon film is put into a rapid thermal annealing system. A [Small] small amount of Ni is deposited on a substrate by sputtering and, successively, thermal treatment is carried out [as well as] while applying an electric field [is applied] thereon. In this case, the temperature of the thermal treatment ranges from 400 to 500°C.

Page 7, Paragraph Beginning at Line 5:

Power needed for depositing Ni ranges from 1 to 100W, which controls the deposition rate [by being manipulated]. The deposition rate [means] is defined as an average amount presumed from deposition area, Ni density and deposition time after the total number of Ni atoms in the crystallized polysilicon film has been calculated by SIMS (secondary ion mass spectroscopy). Such method of metal deposition is simple and important in controlling the amount of metal existing in the film. In this case, the size of the sample is 100x100 mm^2 and a DC bias applied during the thermal treatment ranges from 0 to 1000 V.

Page 7, Paragraph Beginning at Line 12:

Initial vacuum level for Ni deposition is under 10^{-6}Torr and a lamp is arranged in a heating block to heat [a] the sample uniformity. An amorphous silicon film is heated by a ray or heat transferred through a substrate. Metal electrodes are contacted coplanar with both ends of the sample in order to apply uniform electric field to both ends of the amorphous silicon. In this case, the metal for the electrodes is made of MoW or Cr and the contact resistance is 6Ω at [a] room temperature.

Page 7, Paragraph Beginning at Line 20:

Referring to Fig. 1, a polysilicon film 11 which is formed by the above-mentioned method and which contains a small amount of Ni is on an insulating substrate 10 such as a glass substrate.

Page 8, Paragraph Beginning at Line 1:

Referring to Fig. 2, an insulating layer 21 used as a buffer layer is formed on an insulating substrate 20 such as a glass substrate. A polysilicon film 22 which is formed by the above-mentioned method and which contains a small amount of Ni is on an insulating [substrate 20] layer 21.

Page 8, Paragraph Beginning at Line 5:

Fig. 3 shows a first example of the secondary ion mass-spectroscopy of a polysilicon film formed by the first embodiment of the present invention.

Page 8, Paragraph Beginning at Line 7:

Referring to Fig. 3, Ni atoms exist in the polysilicon film [to the] in an amount between $4x10^{18}/cm^3$ (denoted by line(a)) and $2x10^{18}/cm^3$ (denoted by line(b)) [in] on average.

Page 8, Paragraph Beginning at Line 11:

Referring to Fig. 4, each electrical conductivity activation energy of a polysilicon film containing Ni is 0.52 eV (denoted by line (a)) and 0.62 eV (line (b)), respectively. The graph shows the same activated [form of] from a conventional polysilicon film.

Page 8, Paragraph Beginning at Line 14:

Fig. 5 shows a second example of the secondary ion mass-spectroscopy of a polysilicon film formed by the second embodiment of the present invention.

Page 8, Paragraph Beginning at Line 16:

Referring to Fig. 5, Ni atoms exist in the polysilicon film [to the] in an amount between $9x10^{17}/cm^3$ (denoted by line (c)) and $6x10^{17}/cm^3$ (denoted by line (d)) [in] on average.

Page 8, Paragraph Beginning at Line 20:

Referring to Fig. 6, each electrical conductivity activation energy of a polysilicon film containing Ni is 0.64 eV (denoted by line (c)) and 0.71 eV (line (d))[.] , respectively.

Page 8, Paragraph Beginning at Line 22:

Fig. 7 shows a third example of the secondary ion mass-spectroscopy of a polysilicon film formed by the third embodiment of the present invention.

Page 8, Paragraph Beginning at Line 24:

Referring to Fig. 7, Ni atoms exist in the polysilicon film [to the] in an amount of about $1x10^{18}/cm^3$ [in] on average.

Page 9, Paragraph Beginning at Line 7:

Fig. 9 shows a graph of an electrical conductivity activation energy vs. number of Ni atoms contained in the polysilicon film [formed by the embodiment of] according to the present invention.

Page 9, Paragraph Beginning at Line 9:

Referring to Fig. 9, the graph shows electrical conductivity activation energy when Ni atoms exist in the polysilicon film [to the] in an amount between $10^{17}/cm^3$ and $10^{19}/cm^3$ [in] on average.

Page 9, Paragraph Beginning at Line 12:

As the quantity of Ni increases in the film, so do acceptors within a silicon band gap. Thus, electrical conductivity activation energy decreases. [By referring] Referring to the

drawing, as most of Ni atoms do not form acceptors in the polysilicon film, such silicon material can be used for semiconductor device fabrication provided that the number of Ni atoms in the film is under $2x10^{19}/cm^3$ [in] on average.

Page 9, Paragraph Beginning at Line 17:

Fig. 10 shows field effect mobility of a TFT fabricated [in use of] using the polysilicon film [formed by] according to another embodiment of the present invention in accordance with the Ni containment.

Page 9, Paragraph Beginning at Line 20:

Referring to Fig. 10, crystallization is achieved within 10 minutes by applying an electric field during crystallization [of which] at a temperature [is] of about 500°C.

Page 9, Paragraph Beginning at Line 22:

The maximum value of mobility [appears provided that Ni containment] is achieved when the amount of Ni is $2.96x10^{19}/cm^3$.

Page 10, Paragraph Beginning at Line 1:

Mobility decreases greatly [provided that Ni containment] when the amount of Ni is over $10^{20}/cm^3$.

Page 10, Paragraph Beginning at Line 2:

It is impossible to achieve [the] crystallization experimentally within 10 minutes [provided that Ni containment] unless the amount of Ni is under $1x10^{18}/cm^3$.

Page 10, Paragraph Beginning at Line 6:

Fig. 11A shows a [picture of] TEM picture and diffraction patterns of a polysilicon film containing Ni atoms of $1.6x10^{17}atoms/cm^3$ [in] on average.

Page 10, Paragraph Beginning at Line 8:

Referring to Fig. 11A, crystallites 12 of a leaf-like [feature is] shape are verified in an amorphous silicon region 11, showing that crystallization is achieved locally instead of total crystallization of the film.

Page 10, Paragraph Beginning at Line 11:

Fig. 11B shows a [picture of] TEM picture and diffraction patterns of a polysilicon film containing Ni atoms of $4.8x10^{17}$atoms/cm^3 [in] on average.

Page 10, Paragraph Beginning at Line 13:

Referring to Fig. 11B, crystallites 13 [of bar-like feature is] having a needle shape are verified, and the whole amorphous silicon is crystallized uniformly.

Page 10, Paragraph Beginning at Line 15:

Fig. 11C shows a [picture of] TEM picture and diffraction patterns of a polysilicon film containing Ni atoms of $1.6x10^{19}$atoms/cm^3 [in] on average.

Page 10, Paragraph Beginning at Line 17:

Referring to Fig. 11C, it is noted that the film is crystallized by crystallites 13 of a bar-like [feature] shape, and the whole amorphous silicon is crystallized uniformly.

Page 10, Paragraph Beginning at Line 19:

Fig. 11D shows a [picture of] SEM picture and diffraction patterns of a polysilicon film containing Ni atoms of $3x10^{20}$atoms/cm^3 [in] on average.

Page 10, Paragraph Beginning at Line 21:

Referring to Fig. 11D, bar-like crystallites are not identified in the drawing, and the whole film is filled with crystallites 14 of a small circle-like [feature] shape. Such polysilicon fails to be used for fabricating solar cells, thin film transistors, and the like.

Page 11, Paragraph Beginning at Line 2:

Referring to Fig. 12A, each crystallite [of bar-like feature] having a needle shape grows from a nucleus for crystallization in a certain direction by the movement of $NiSi_2$ in the early stage of crystallization, respectively.

Page 11, Paragraph Beginning at Line 5:

Referring to Fig. 12B, this crystallite [of bar-like feature] having a needle shape grows continuously until this crystallite collides with other crystallites grown from other nucleuses and stops its growth.

Page 11, Paragraph Beginning at Line 8:

Referring to Fig. 12C, an amorphous silicon thin film is crystallized by a number of crystallites [of bar-like feature] having a needle shape.

Page 11 Paragraph Beginning at Line 10:

As mentioned in the above description of the present invention, a polysilicon film containing Ni [of which] having a density in the range of [ranges] $2x10^{17}$ and $5x10^{19}$atoms/cm^3 consists of bar-like silicon crystallites, and the whole part of the polysilicon film is crystallized uniformly.

Page 11, Paragraph Beginning at Line 19:

It will be apparent to those skilled in the art that various modifications and variations can be made in polycrystalline silicon containing Ni of the present invention without departing from the spirit or scope of the [inventions] invention. Thus, it is intended that the present invention cover the modifications and variations of this invention provided they come within the scope of the appended claims and equivalents.

EXHIBIT II – MARKED UP VERSION OF THE AMENDED ABSTRACT

The present invention is related to a polycrystalline silicon film containing Ni which is formed by crystallizing an amorphous silicon layer containing nickel. The present invention includes a polycrystalline silicon film wherein the polycrystalline film contains Ni atoms of which density ranges from $2x10^{17}$ to $5x10^{19}$atoms/cm^3 [in] on average and comprises a plurality of [bar-like] needle-shaped silicon crystallites. In another aspect, the present invention includes a polycrystalline silicon film wherein the polycrystalline film contains Ni atoms of which density ranges from $2x10^{17}$ to $5x10^{19}$atoms/cm^3, comprises a plurality of [bar-like] needle-shaped silicon crystallites and is formed on an insulating substrate. Such a polysilicon film according to the present invention avoids metal contamination usually generated in a conventional method of metal induced crystallization. [Accordingly, the polysilicon film of the present invention is applied to the fabrication of a TFT-LCD, a solar cell, etc. instead of polysilicon crystallized by the current laser crystallization.]

EXHIBIT III – MARKED UP VERSION OF THE AMENDED CLAIMS

1. (Amended) A polycrystalline silicon film, the polycrystalline film containing Ni atoms of which density ranges $2x10^{17}$ to $5x10^{19}$atoms/cm^3 [in] on average, and an electrical conductivity activation energy between 0.52eV and 0.71eV, the polycrystalline silicon film comprising a plurality of [bar-like] needle-shaped silicon crystallites.

3. (Amended) A polycrystalline silicon film, the polycrystalline film containing Ni atoms of which density ranges $2x10^{17}$ to $5x10^{19}$atoms/cm^3, and an electrical conductivity activation energy between 0.52eV and 0.71eV, the polycrystalline silicon film comprising a plurality of [bar-like] needle-shaped silicon crystallites, the polycrystalline silicon film on an insulating substrate.

6. (Amended) A polycrystalline silicon film, the polycrystalline film containing metal of which density ranges $2x10^{17}$ to $5x10^{19}$atoms/cm^3, and an electrical conductivity activation energy between 0.52eV and 0.71eV, the polycrystalline silicon film comprising a plurality of [bar-like] needle-shaped silicon crystallites wherein the metal is a catalyst for metal induced crystallization of silicon.

9. (Amended) A polycrystalline silicon film, the polycrystalline film containing metal of which density ranges $2x10^{17}$ to $5x10^{19}$atoms/cm^3, and an electrical conductivity activation energy between 0.52eV and 0.71eV, the polycrystalline silicon film comprising a plurality of [bar-like] needle-shaped silicon crystallites wherein the metal is a catalyst for metal induced crystallization of amorphous silicon.